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Luminescence Intensity Ratio Thermometry with trivalent lanthanides: modelling and simulation using Judd-Ofelt theory

Abstract:

Rare-earth elements are revolutionizing modern society. Their demand and research popularity is booming. Emissions of trivalent lanthanides are characterized by sharp lines in emission spectra, long lifetimes, and high quantum yields. Spectroscopically unique due to the shielded 4f electron configuration, the explanation of their emission intensities remained a puzzle until 1962, when Judd and Ofelt simultaneously published papers presenting the Quantum mechanical model that today bears their name. Judd-Ofelt theory (JO) presents the only theory that explains the optical transition intensities of trivalent lanthanides.

Lanthanides have many merits to be used in luminescent thermometry, and they are most frequently researched by the Luminescence Intensity Ratio (LIR) method. Thus, the question of whether the JO can be used to predict the thermometric figures of merit of LIR imposed itself.

In recent work, we presented the JO thermometric model that showed how JO in combination with LIR can indeed predict the temperature-independent B parameter, absolute sensitivity, and temperature resolution [1]. From the JO parameters obtained by the JOES software we developed [2], the test provided high matching with the experimental data on Eu^{3+} doped sample. The explicit equations for all relevant Lanthanides and transitions were given, and the interactive software is published to ease this task.

A novel thermometric method of dual-excited single band ratiometric LIR was analogously theoretically put under testing, with a modified JO model that this time requires correction factors [3]. The results showed once again the high matching with the experimental LIR.

In conclusion, the JO thermometric model can be used for primal selection of phosphors before doing the arduous thermometric experiments, as the figures of merit can be predicted with satisfactory accuracy, and the JO parameters can be obtained from a single room-temperature spectrum or vast literature.

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[3] A. Ćirić, I. Zeković, M. Medić, Ž. Antić, M.D. Dramićanin, Judd-Ofelt modelling of the dual-excited single band ratiometric luminescence thermometry, J. Lumin. 225 (2020). https://doi.org/10.1016/j.jlumin.2020.117369.